

WHAT IS CLAIMED IS:

1. A method of making a nitrogen oxide sensing element comprising:
incorporating a diazotizing reagent which reacts with nitrous ions to produce
a diazo compound and a coupling reagent which couples with the diazo compound
5 to produce an azo dye into a sol; and
allowing the sol to gel;
wherein the gel comprises a microporous optically transparent inorganic
matrix comprising immobilized diazotizing reagent and immobilized coupling
reagent.
- 10 2. The method of Claim 1, wherein the sol comprises a metal alkoxide or a
metalorganic compound.
3. The method of Claim 1, wherein the sol comprises an alkoxy silane.
4. The method of Claim 1, wherein the sol comprises tetramethyl
orthosilicate (TMOS).
- 15 5. The method of Claim 1, wherein the diazotizing reagent is sulfanilamide
(SFA).
6. The method of Claim 1, wherein the coupling reagent is N,N-dimethyl-1-
naphthylamine (DMNA).
7. The method of Claim 1, further comprising transferring the sol into the
20 cavity of a mold and allowing the sol to gel in the mold.
8. The method of Claim 7, wherein the mold is a tube and wherein the
cavity of the mold is the hollow interior of the tube.
9. The method of Claim 1, wherein the sol is formed into a film.

10. The method of Claim 1, wherein the sensing element comprises equal molar proportions of diazotizing reagent and coupling reagent.

11. The method of Claim 7, wherein the tube comprises polytetrafluorethylene (PTFE).

5 12. A nitrogen oxide sensing element made by the method of Claim 1.

13. The sensing element of Claim 12, wherein the shape of the sensing element is a cylindrical solid body.

14. The sensing element of Claim 12, wherein the sensing element is a film.

15 15. The sensing element of Claim 12, wherein the shape of the sensing
10 element is a disc.

16. A nitrogen oxide sensor comprising:

a sensing element as set forth in Claim 12;

a light source; and

an optical detector;

15 wherein the sensing element is coupled to the light source by one or more
transmitting optical fibers and wherein the sensing element is coupled to the
detector by one or more receiving optical fibers such that light from the light source
is transmitted through the one or more transmitting optical fibers and impinges on
the sensing element and light impinging on the sensing element is transmitted
20 through the one or more receiving optical fibers to the detector.

17. The sensor of Claim 16, wherein the transmitting and receiving optical fibers are combined in the form of a Y-shaped optical cable having a single distal end comprising ends of both transmitting and receiving fibers, a first proximal end

comprising the ends of one or more transmitting fibers and a second proximal end comprising the ends of one or more receiving fibers;

wherein the distal end of the Y-shaped optical cable is placed in optical communication with the sensing element;

5 wherein the first proximal end of the Y-shaped optical cable is placed in optical communication with the light source; and

wherein the second proximal end of the Y-shaped optical cable is placed in optical communication with the detector.

18. The sensor of Claim 17, wherein the optical cable comprises a single
10 transmitting fiber and a plurality of receiving fibers.

19. The sensor of Claim 18, wherein the single transmitting fiber is surrounded by the plurality of receiving fibers at the distal end of the optical fiber cable.

20. The sensor of Claim 18, wherein the optical cable comprises six
15 receiving fibers.

21. The sensor of Claim 16, wherein the sensing element is in the form of a film.

22. The sensor of Claim 21, further comprising a mirror, wherein the mirror is positioned adjacent the sensing device such that light transmitted from the one or
20 more transmitting fibers through the sensing element is reflected by the mirror, passes through the sensing element a second time and is transmitted into and through the one or more receiving fibers to the detector.

23. The sensor of Claim 21, wherein ends of the transmitting and receiving fibers adjacent the sensing element are positioned on the same side of the film sensing element.

24. The sensor of Claim 23, wherein the sensing device is in the form of a film and wherein the sensing element is positioned such that light impinging on the sensing element is reflected by the sensing element into one or more receiving fiber ends.

25. The sensor of Claim 24, wherein the sensor does not comprise a mirror.

26. The sensor of Claim 16, wherein the sensing element is in the form of a three-dimensional elongate solid body having a proximal end and a distal end.

27. The sensor of Claim 26, wherein the proximal end of the sensing element is positioned adjacent ends of the one or more transmitting fibers and wherein the distal end of the sensing element is positioned adjacent ends of the one or more receiving fibers such that light transmitted through the transmitting fibers passes through the sensing element and through the receiving fibers to the detector.

28. The sensor of Claim 16, wherein the sensing element is in the shape of a cylindrical solid body.

29. The sensor of Claim 21, wherein ends of the transmitting and receiving fibers adjacent the sensing element are bundled into an optical fiber cable having a planar cable end adjacent the sensing element, and wherein the planar surface of the film sensing element is oriented at an angle to the planar cable end adjacent the sensing element.

30. The sensor of Claim 29, wherein the angle of orientation of the film sensing element to the planar cable end is the Brewster's angle (β_B) as calculated from the refractive index of the sensing element (n_2) and the refractive index of the medium through which the light travels before impinging on the sensing element (n_1) as set forth below:

$$\beta_B = \arctan\left(\frac{n_2}{n_1}\right).$$

31. The sensor of Claim 16, wherein the light source has a spectral distribution ranging from 250 nm to 870 nm.

32. The sensor of Claim 16, wherein the detector is a spectrometer.

33. The sensor of Claim 32, wherein the spectrometer comprises a grating and a CCD, wherein light transmitted from the sensing element to the detector passes through the grating and impinges on the CCD.

34. The sensor of Claim 16, further comprising a personal computer interfaced to the detector for collecting data.

35. A nitrogen oxide sensing element comprising:
a microporous matrix of an optically transparent inorganic compound;
a diazotizing reagent which reacts with nitrous ions to produce a diazo compound; and
a coupling reagent which couples with the diazo compound to produce an azo dye;

wherein the diazotizing reagent and the coupling reagent are immobilized in the microporous matrix.

36. The sensing element of Claim 35, wherein the microporous matrix comprises a metalorganic compound.

5 37. The sensing element of Claim 35, wherein the microporous matrix comprises SiO₂.

38. The sensing element of Claim 35, wherein the diazotizing reagent and the coupling reagent are present in equal molar proportions.

39. The method of Claim 35, wherein the diazotizing reagent is
10 sulfanilamide (SFA).

40. The method of Claim 35, wherein the coupling reagent is N,N-dimethyl-1-naphthylamine (DMNA).

41. A nitrogen oxide sensor comprising:

a film sensing element comprising a microporous matrix of an optically
15 transparent material, a diazotizing reagent which reacts with nitrous ions to produce a diazo compound and a coupling reagent which couples with the diazo compound to produce an azo dye;

a light source; and

an optical detector;

20 wherein the sensing element is coupled to the light source by one or more transmitting optical fibers and wherein the sensing element is coupled to the detector by one or more receiving optical fibers such that light from the light source is transmitted through the one or more transmitting optical fibers and impinges on

the sensing element and light impinging on the sensing element is transmitted through the one or more receiving optical fibers to the detector; and

wherein ends of the transmitting and receiving fibers adjacent the sensing element are positioned on the same side of the film sensing element.

5 42. The sensor of Claim 41, further comprising a mirror, wherein the mirror is positioned adjacent the sensing element opposite the ends of the transmitting and receiving fibers such that light transmitted from the one or more transmitting fibers through the sensing element is reflected by the mirror, passes through the sensing element a second time and is transmitted into and through the one or more receiving
10 fibers.

43. The sensor of Claim 41, wherein the film sensing element is positioned such that light impinging on the sensing element is reflected by the sensing element into one or more receiving fiber ends.

44. The sensor of Claim 43, wherein the sensor does not comprise a mirror.

15 45. The sensor of Claim 43, wherein ends of the transmitting and receiving fibers adjacent the sensing element are bundled into an optical fiber cable having a planar cable end adjacent the film sensing element, and wherein the planar surface of the film sensing element is oriented at an angle to the planar cable end adjacent the sensing element.

20 46. The sensor of Claim 45, wherein the angle of orientation of the film sensing element to the planar cable end is the Brewster's angle (β_B) as calculated from the refractive index of the sensing element (n_s) and the refractive index of a

medium through which the light travels before impinging on the sensing element

(n_1) as set forth below:

$$\beta_B = \arctan\left(\frac{n_2}{n_1}\right).$$